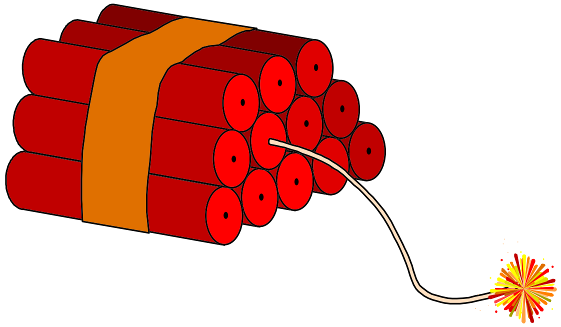
# HE MATERIAL MODELING AND VALIDATION



JOBIE M. GERKEN

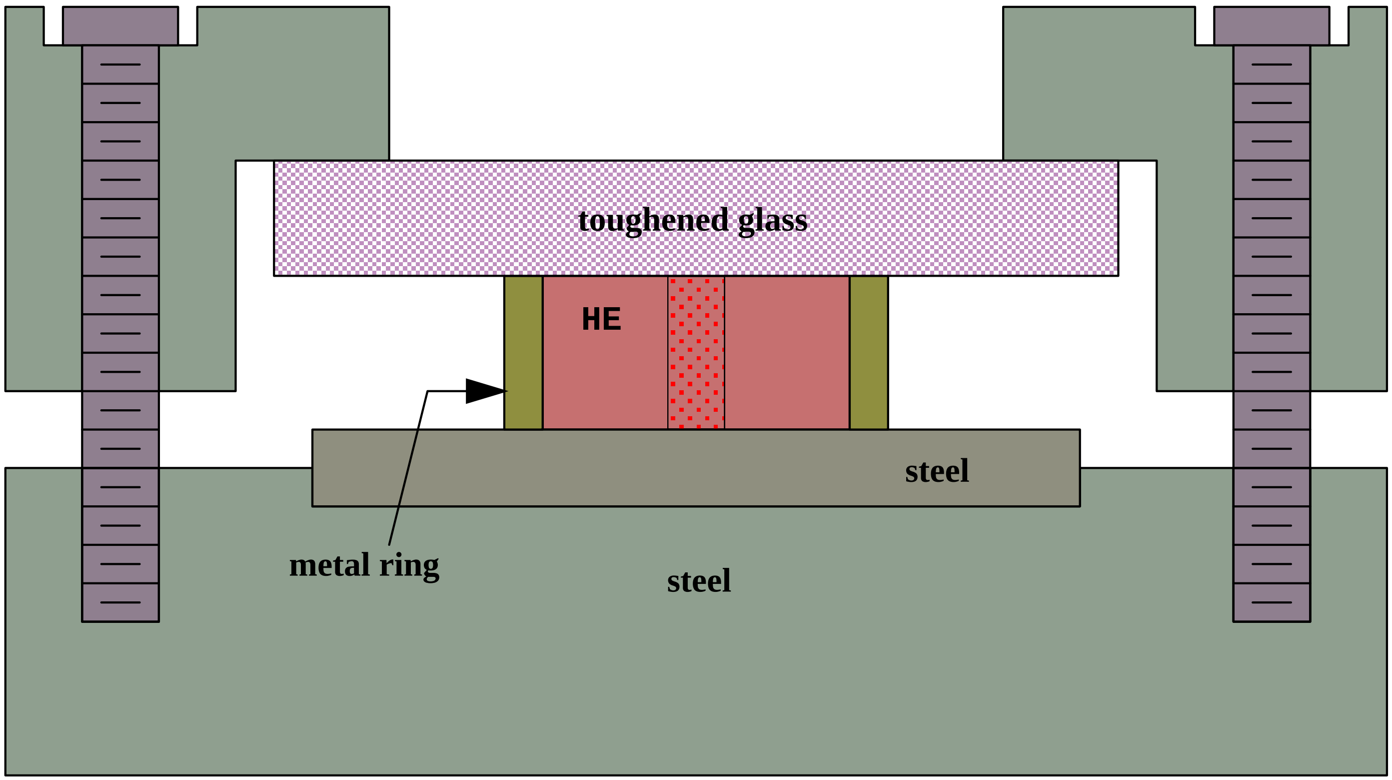
JOEL G. BENNETT

ESA-EA

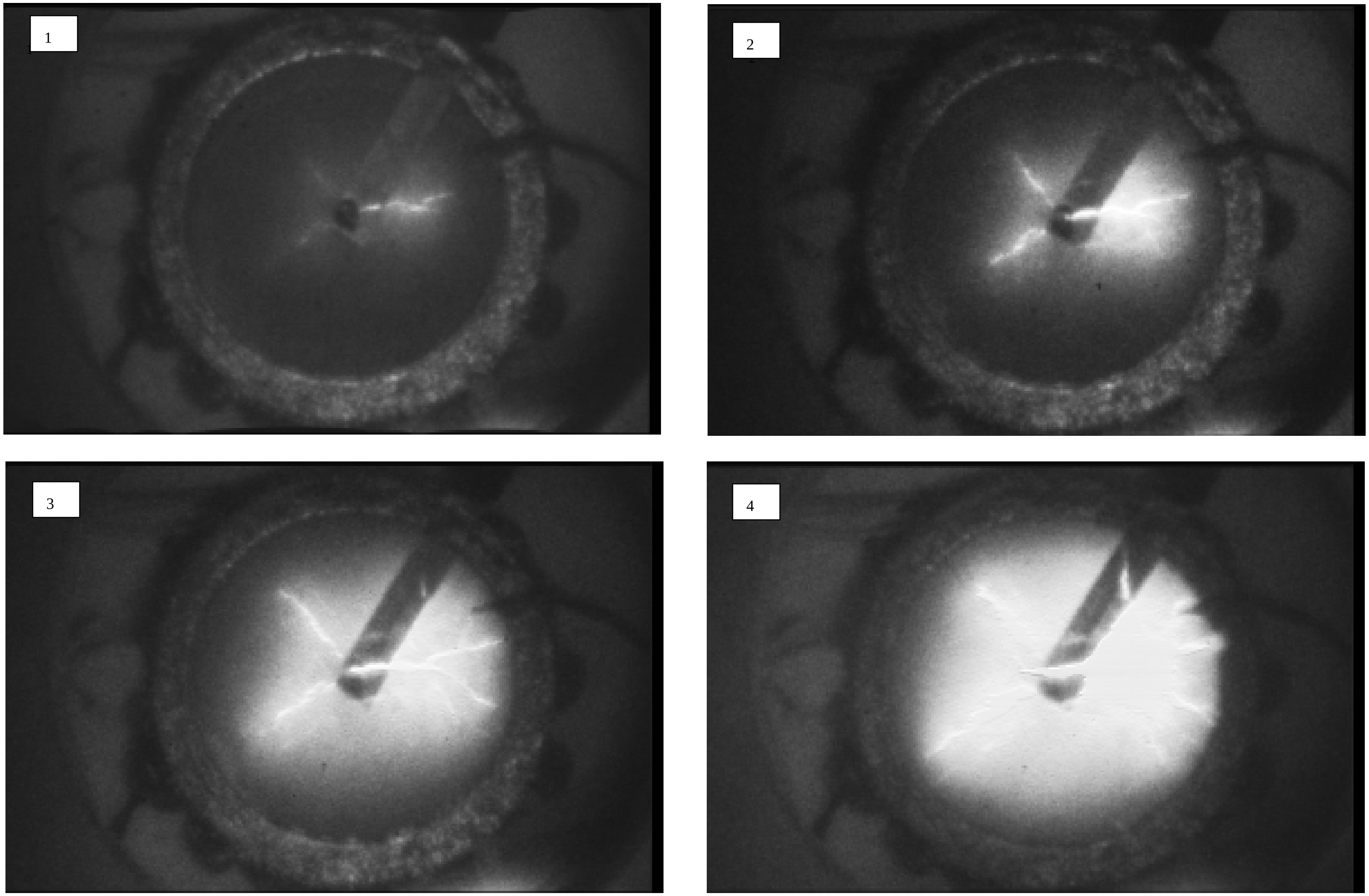
# A TRUE TEAM EFFORT

| | |
|---|---|
| **Frank Addessio T-3** | **Joel Bennett ESA-EA** |
| **Mike Stout MST-7** | **Keith Haberman ESA-EA** |
| **Jim Johnson T-7** | **Bob Hackett "Ole" Miss.** |
| **John Dienes T-14** | **Fred Smith CSU** |
| **Supported by:** | **Blaine Asay DX-2** |
| **Phil Howe** | **Deanne Idar DX-2** |
| **Joe Repa** | **Colin Sadler DX-2** |
| **George Hurley** | **Cheng Liu MST-7** |
| | **G.T. "Rusty" Gray MST-8** |

# Mechanically Coupled Cook-Off



# Mechanically-Coupled Cookoff Results



# Mechanically Coupled Cookoff

- **An “Engineering Simulation Challenge”**
- **Requires “lots” of tools to come together in the same place, (i.e. in the same code)**
  - **Thermal stress because of heat-up (implies an implicit code capability)**
  - **Discrete cracking model - Gerken/Smith/Bennett**
  - **HE material model (Implicit ViscoSCRAM)**
  - **HE damage cracking model (ViscoSCRAM)**
  - **Bulk thermal heating model (ViscoSCRAM)**
  - **HE ignition model (ViscoSCRAM)**

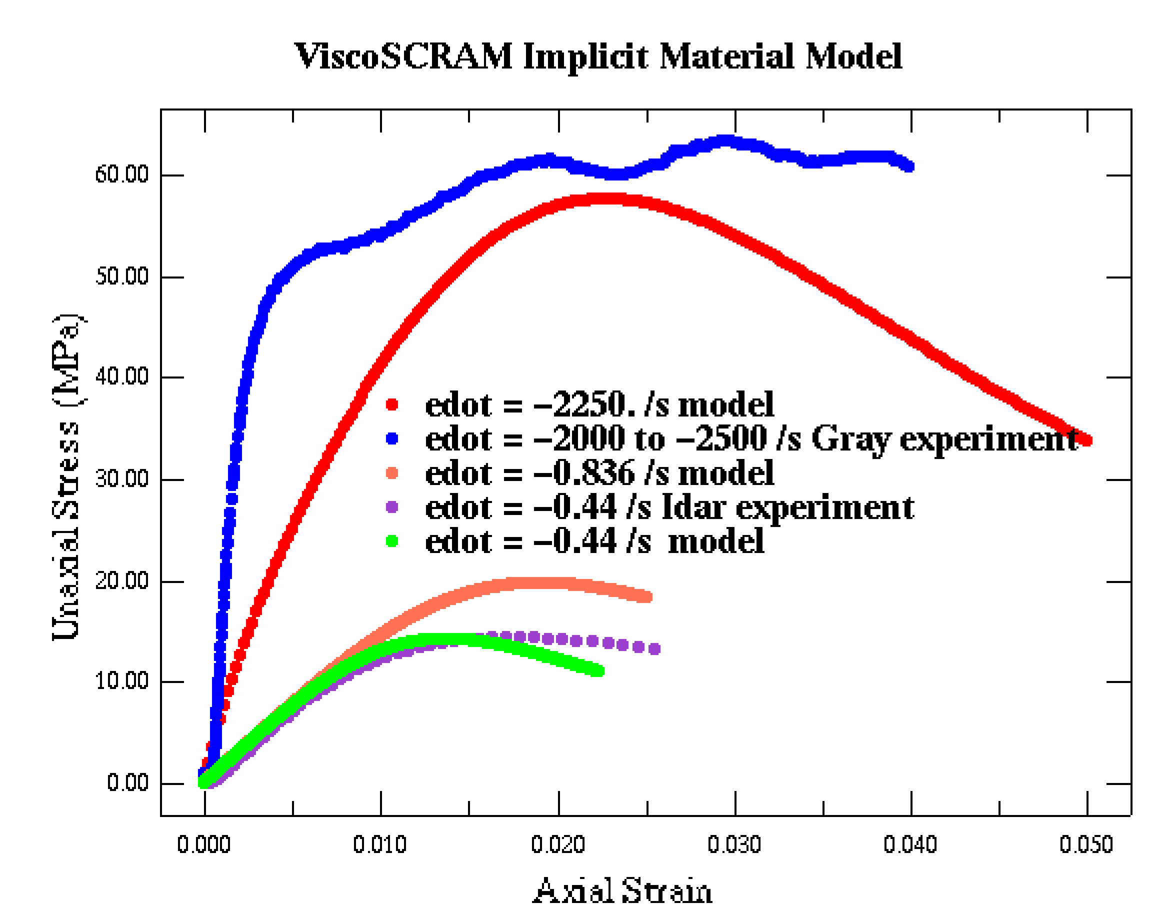
# ViscoSCRAM for PBX 9501

- Viscoelastic material behavior with shear and tensile average crack growth and resulting damage accumulation (SCRAM).
- Bulk thermal heating and frictional hotspot ignition model.
- Implemented in the explicit codes DYNA3D, PRONTO3D, and SHAVANO/KITO and in an implicit form for ABAQUS Standard.

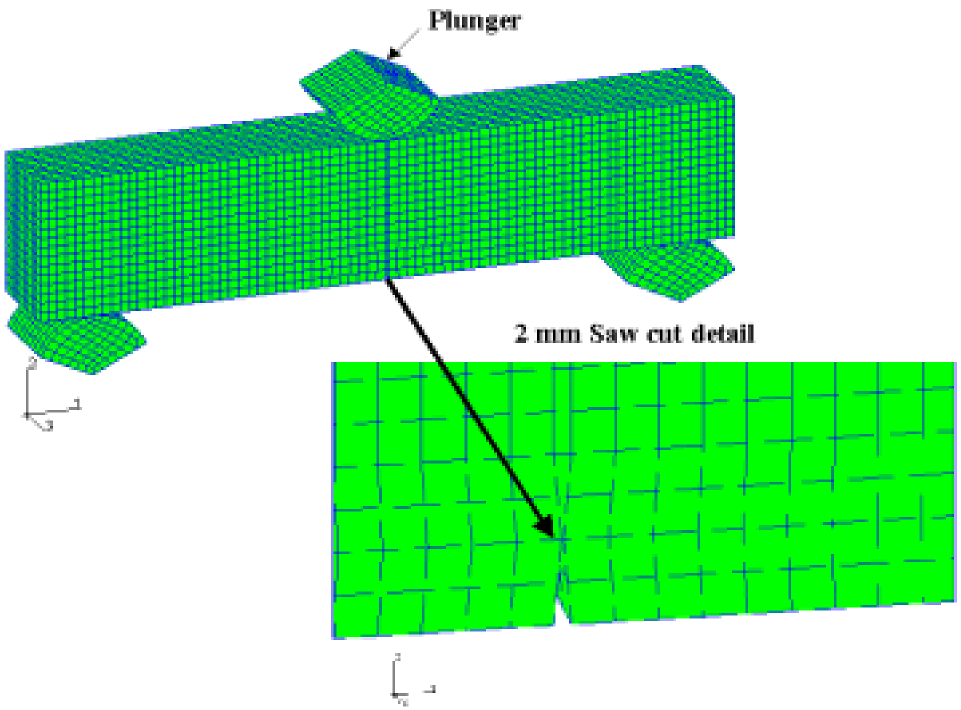
# Validation of ViscoSCRAM

- One Dimensional Compression Tests
  – Low Rate - D. Idar, 0.001 to 0.44 /s tests
  – Higher Rate - G.T. Gray 2000-2500 /s “Hoppy” Bar tests
- Sadler 3 Point Notched Beam Experiments
- Asay Impact Tests
- Idar Steven’s Impact Ignition Tests

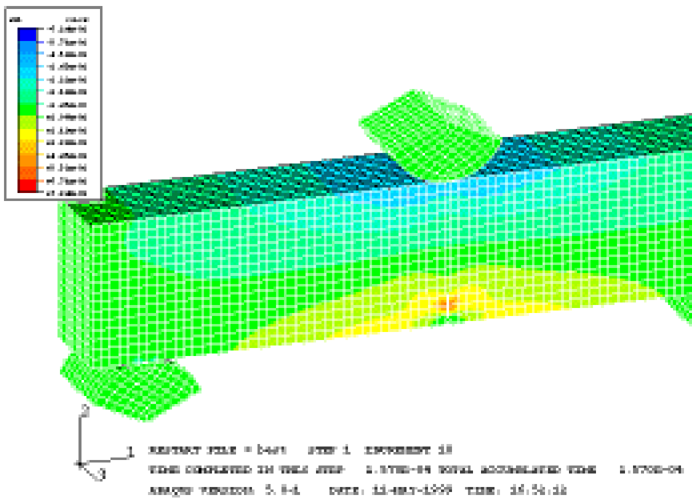
# Idar/Gray Tests Comparison

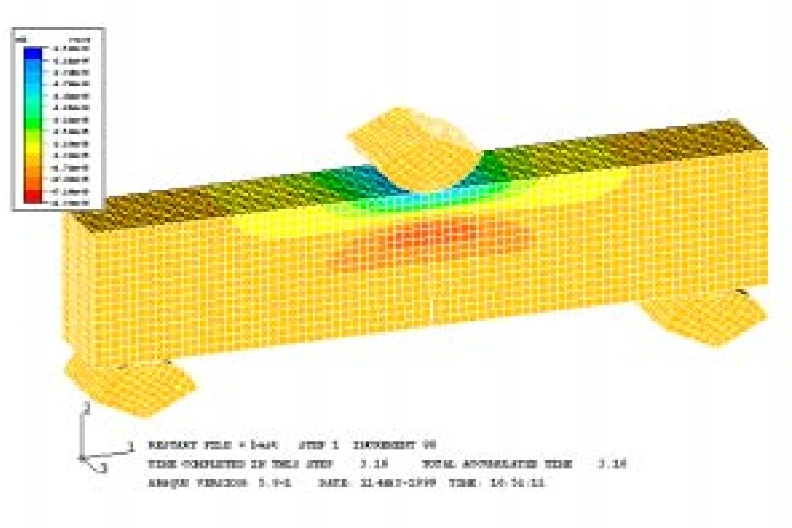


# Sadler 3-Point Beam Damage/Fracture Experiment

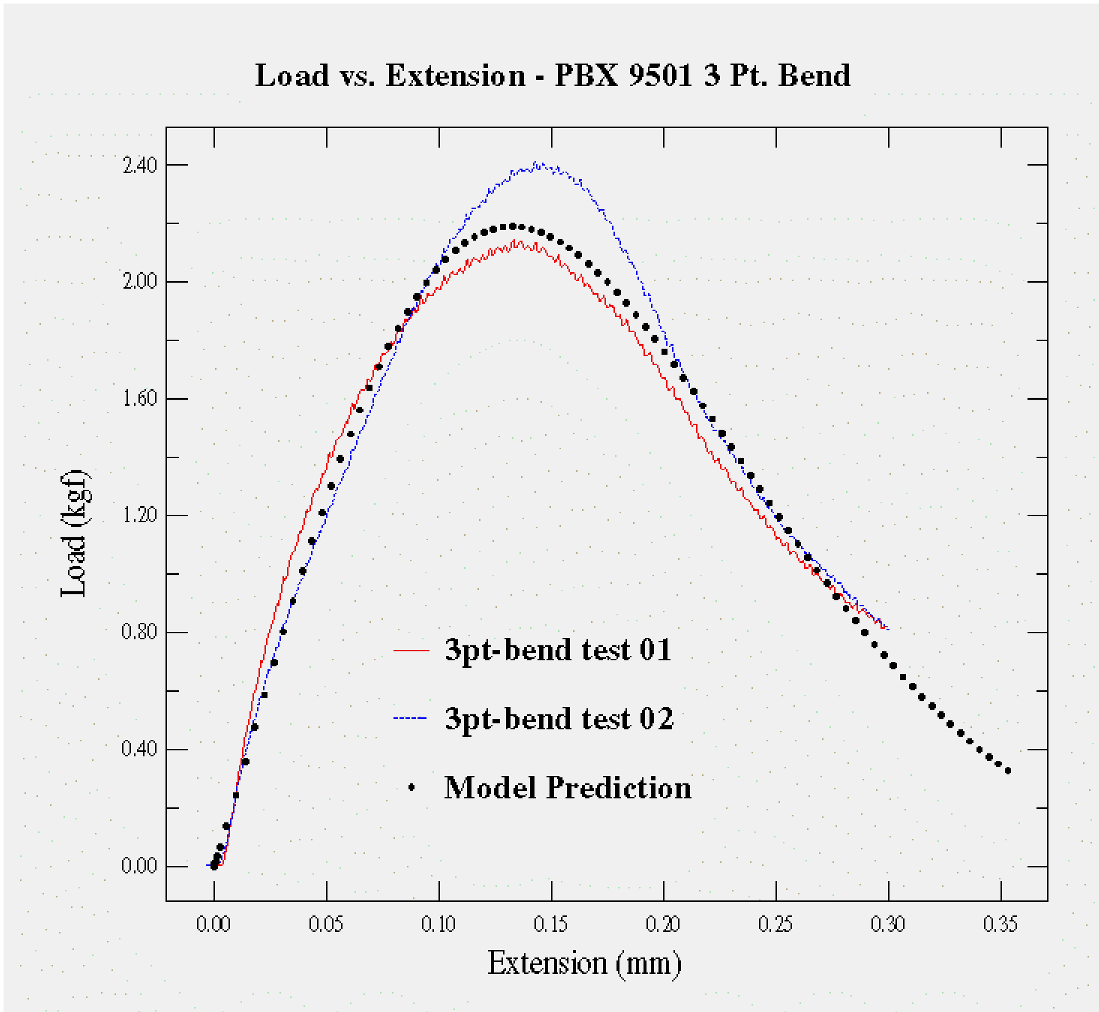


# ViscoSCRAM Damage Progression

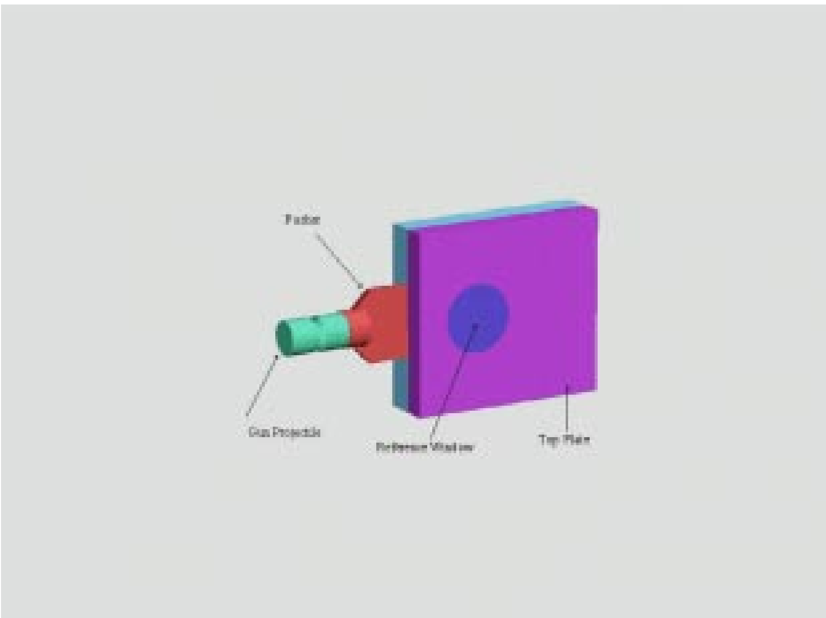


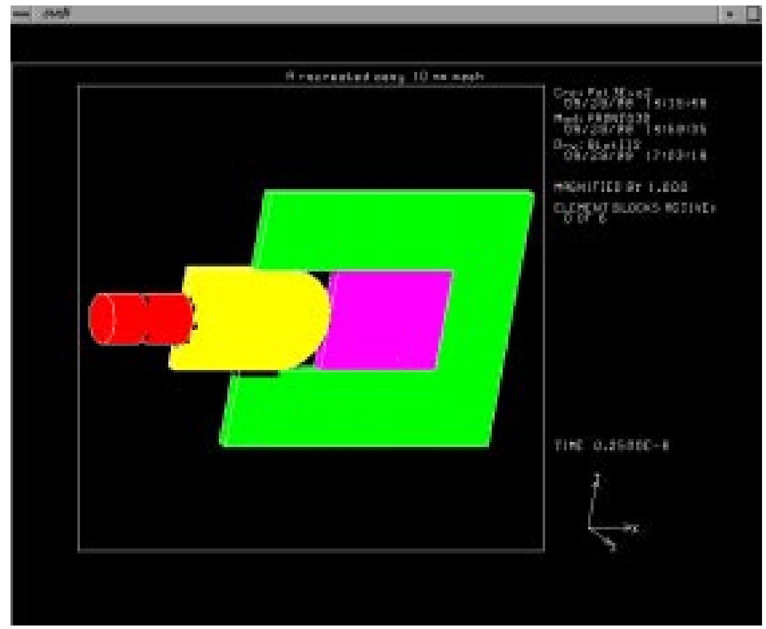


# ViscoSCRAM Comparison

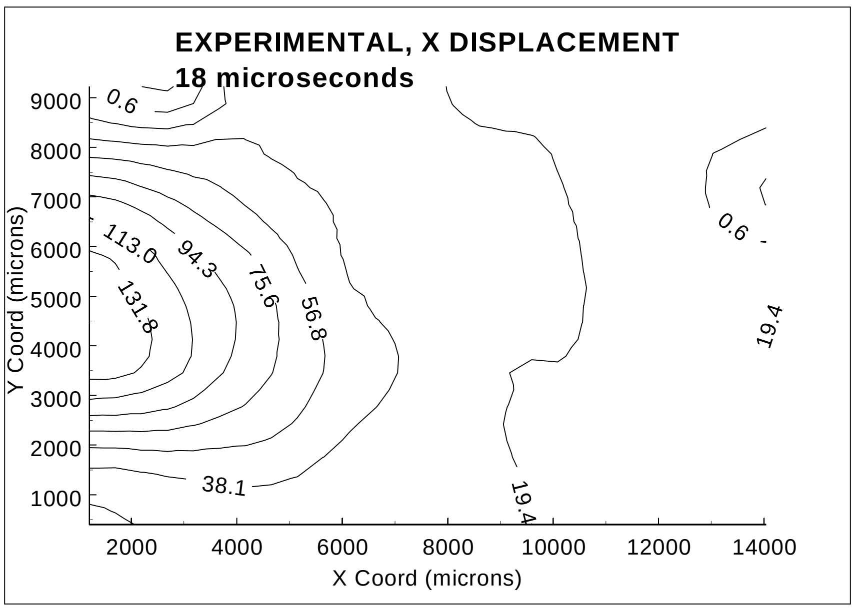


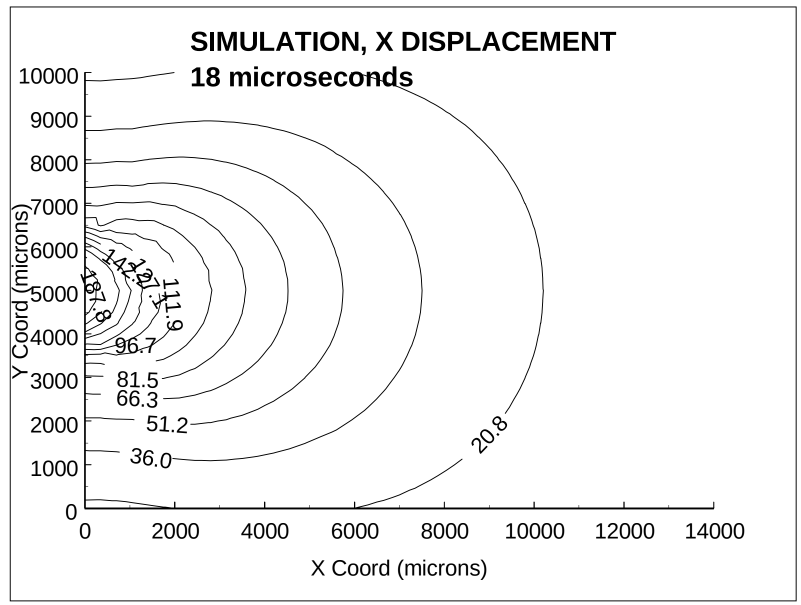
# ASAY Impact Test



# ASAY Impact Comparison



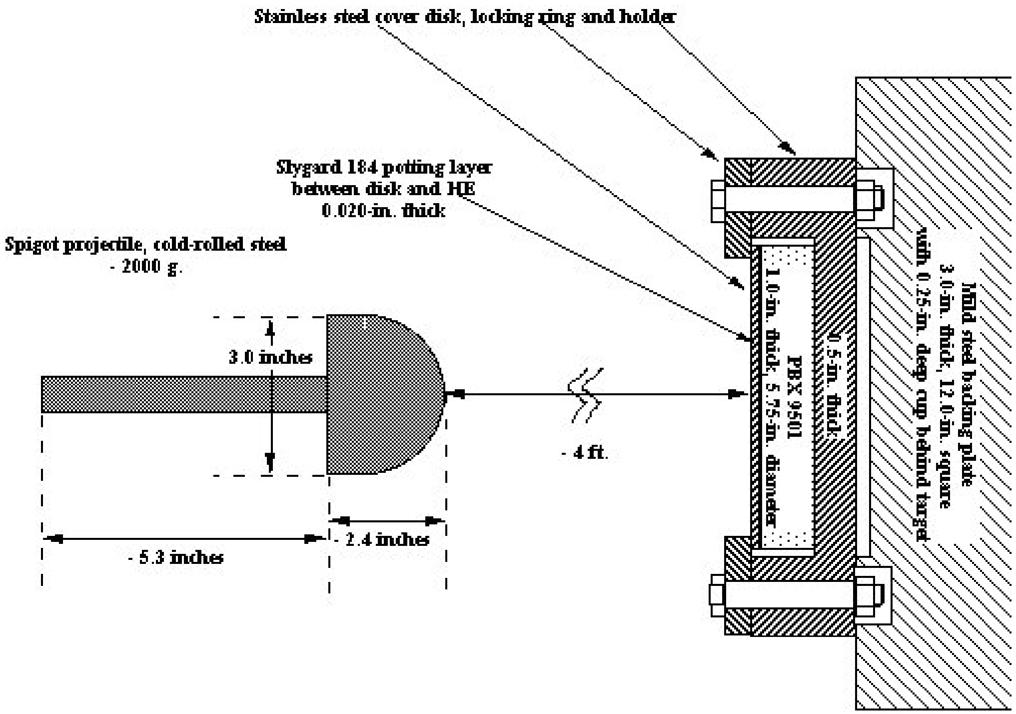



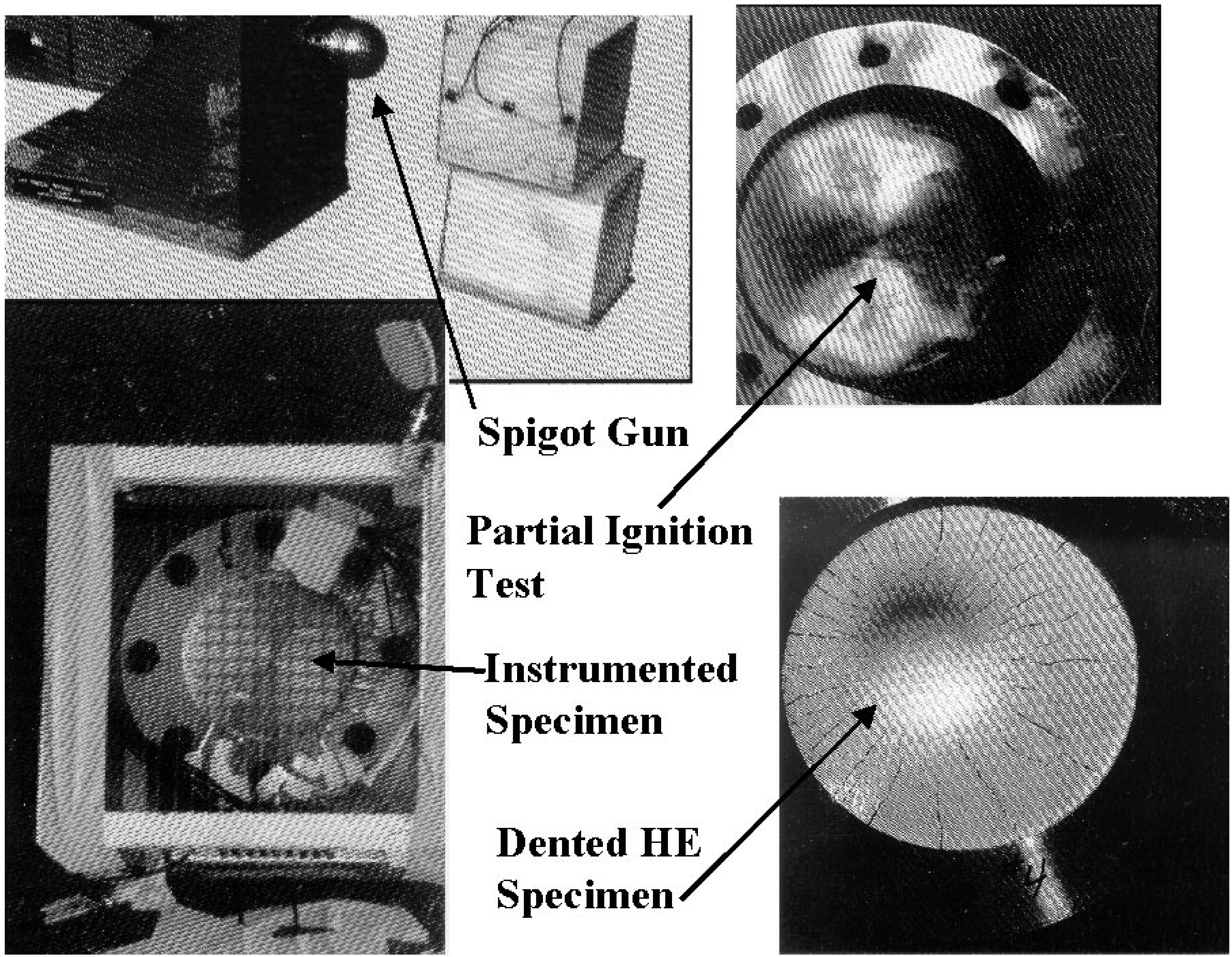

**Engineering Analysis ESA-EA Los Alamos National Laboratory**

# Modeling of Idar’s Spigot Gun (Steven’s) Tests for Ignition Response Parameter Calibration are “in Progress”

# Validation of ViscoSCRAM

- Stevens Impact Test

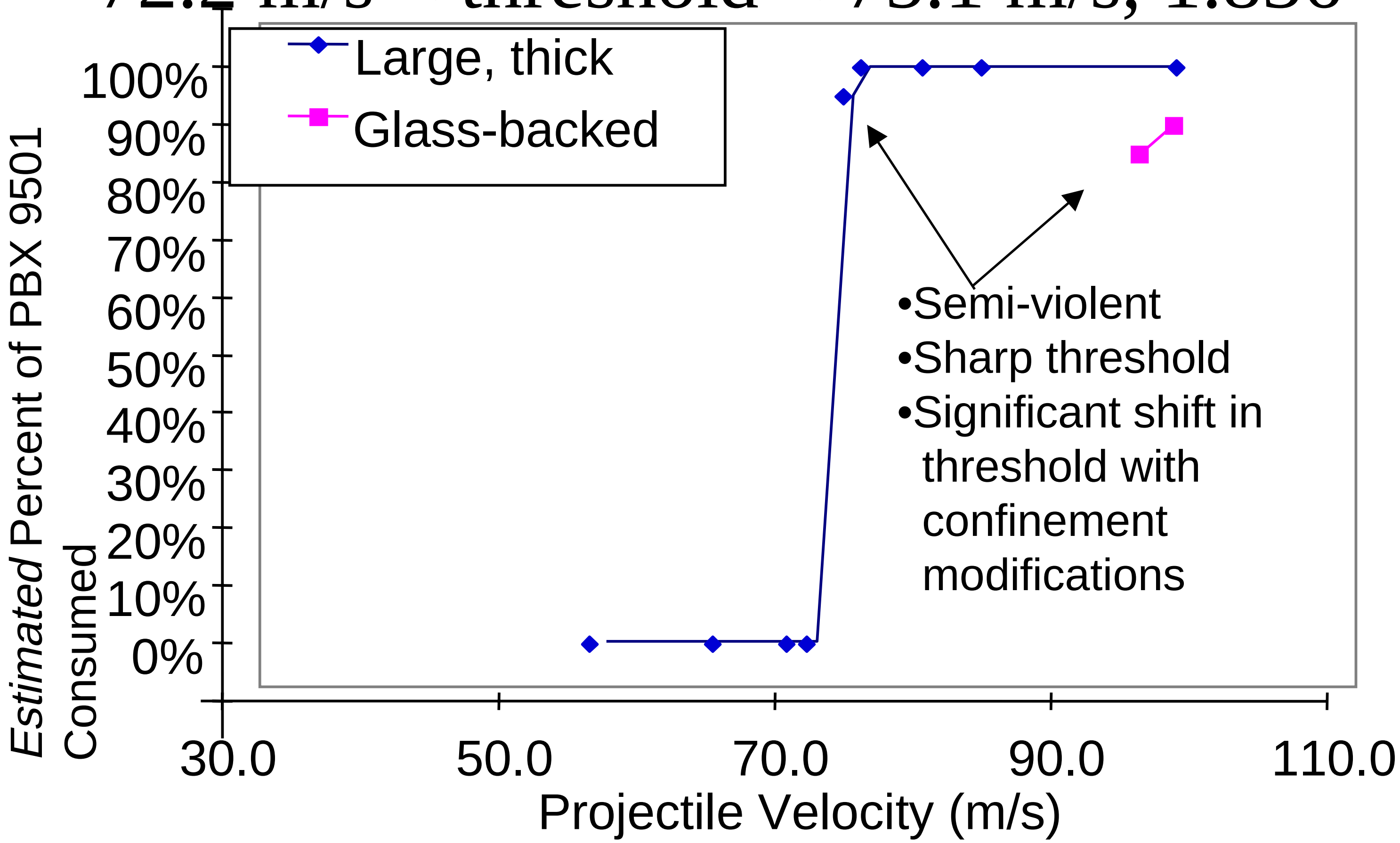



Spigot Gun
Partial Ignition
Test
Instrumented
Specimen
Dented HE
Specimen

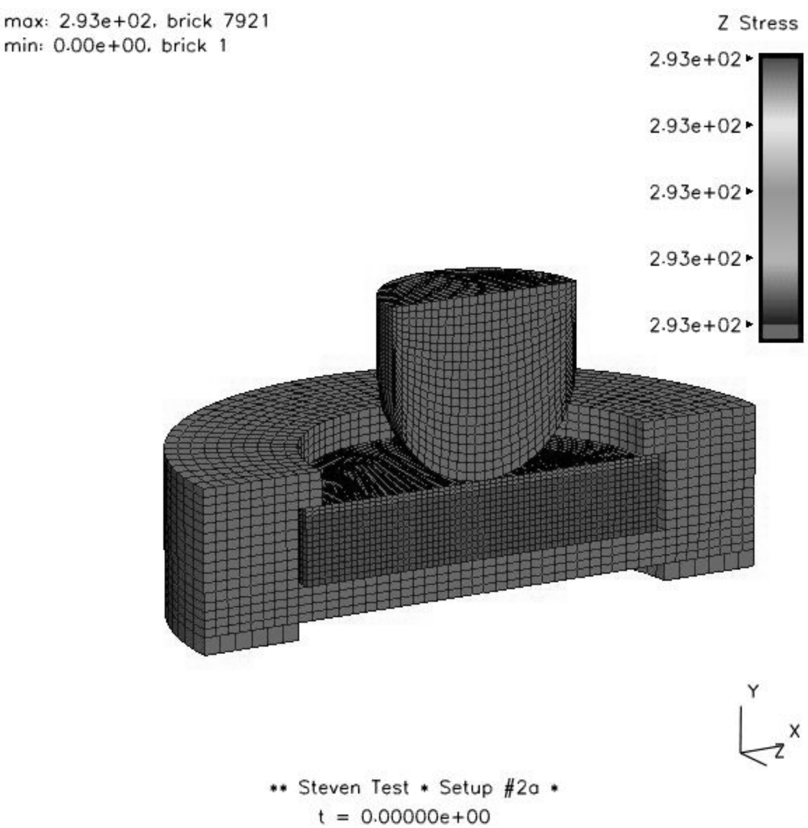
# Idar Steven's Ignition Test

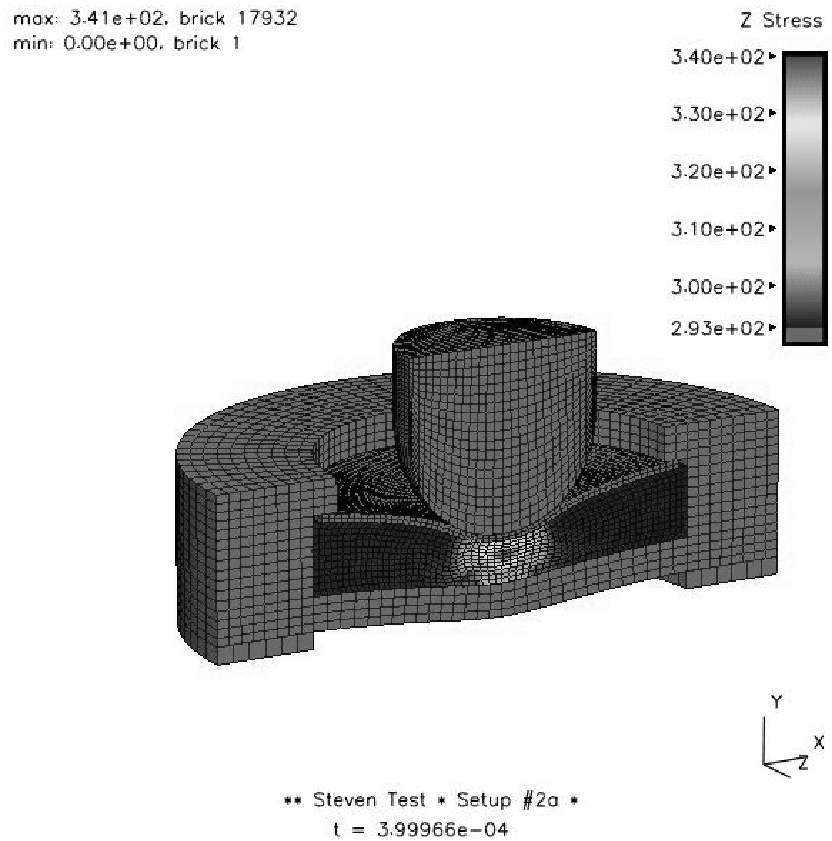
## PBX 9501 Large, Thick Targets

## 72.2 m/s < threshold < 75.1 m/s, 1.836



# Ignition Model Calibration
# "In Progress"



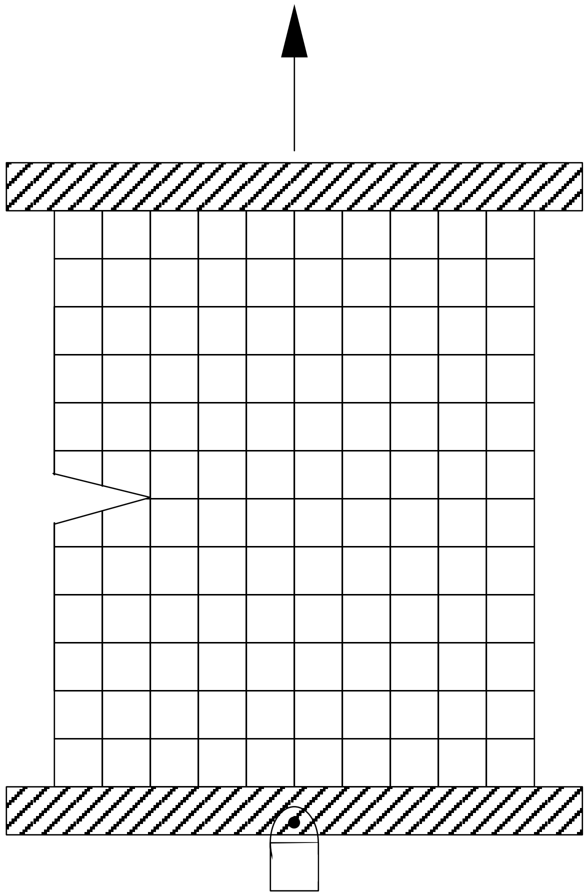



# Discrete Fracture Model Summary

- Based on the microscale-fracture modeling concepts of Alan Needleman (Brown U.), as modified to a mesoscale-fracture structural concept by Gerken/Smith/Bennett.
- Distributed randomly sized meso-scale interface fractures advance because of locally evaluated stress and material state to coalesce into finite discrete fractures.

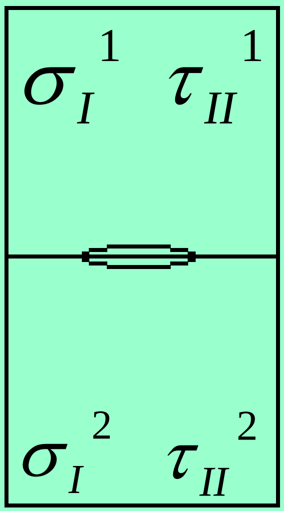
# Discrete Fracture Model

- Cracks Propagate Along Element Interfaces
- Unique Nodal Connectivity for Each Element
  - Maintain Nodal Connectivity
  - No Remeshing



# Discrete Fracture Model

- Interface Failure



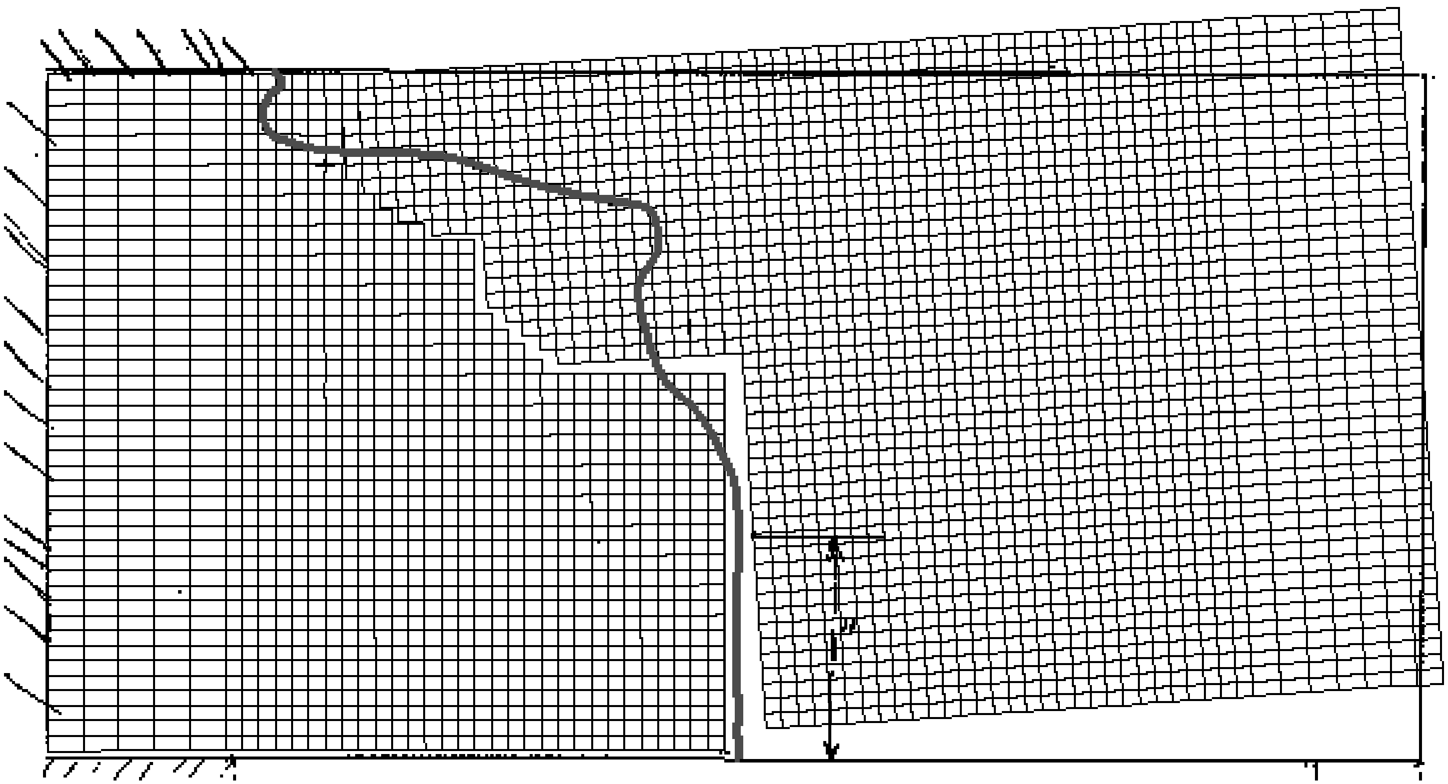

$$\sigma_I = \frac{\sigma_I^1 + \sigma_I^2}{2}$$

$$\tau_{II} = \frac{\tau_{II}^1 + \tau_{II}^2}{2}$$

# Discrete Fracture Model Summary

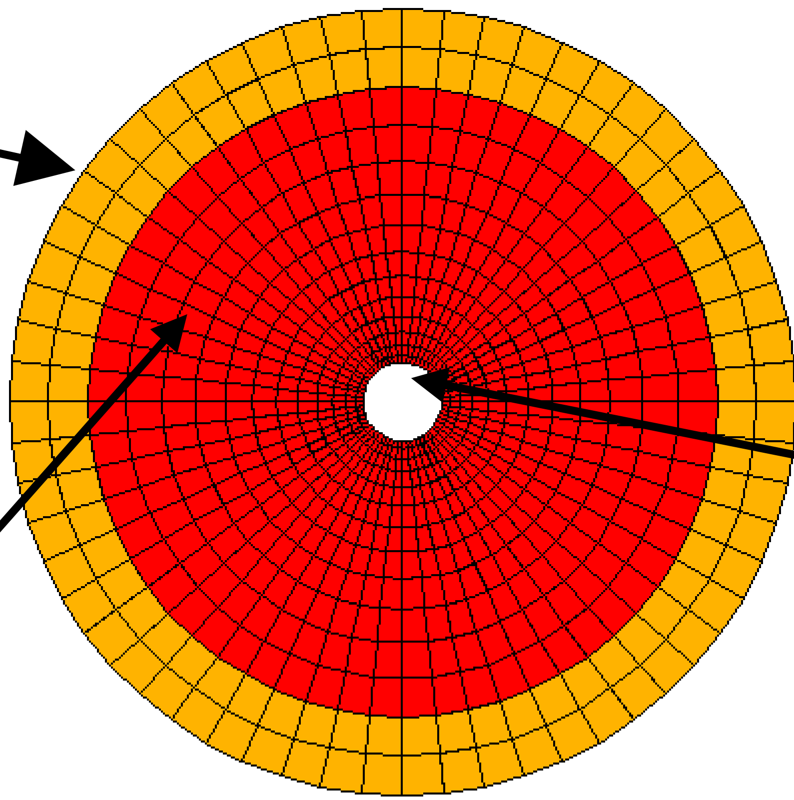
- Simple in concept, but rich in Engineering Fracture Mechanics theory, and not easily implemented.
- "An Implicit Finite Element Method for Discrete Dynamic Fracture", by Jobie M. Gerken, a Master's Thesis in Mechanical Engineering submitted to the Colorado State University (Oct. 1998).

# Discrete Fracture Model



# Modeling MCCO

Copper sleeve

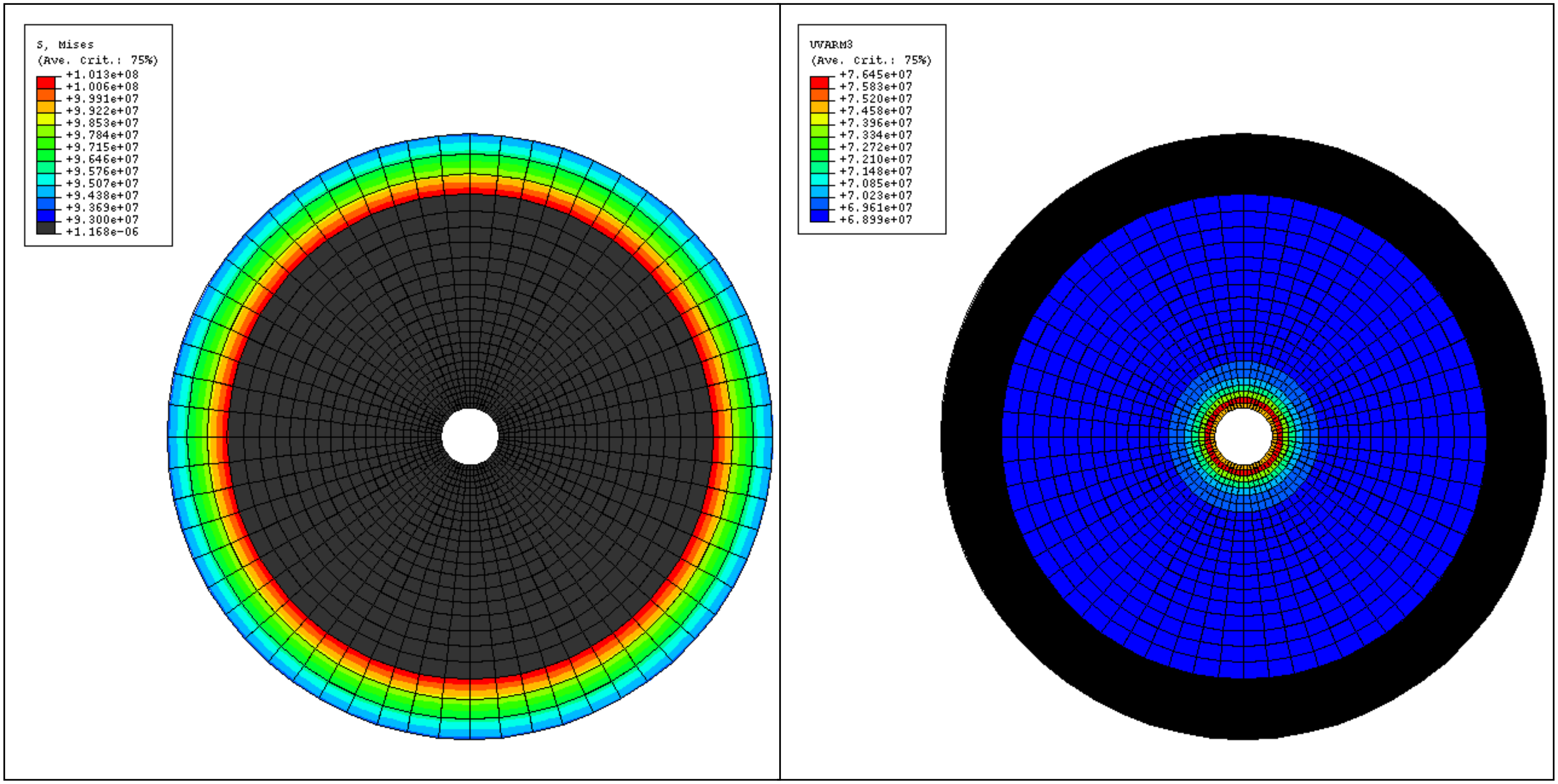


ViscoSCRAM HE with random crack size seeded in each interface

Heat-up followed by a Pressure vs. time event applied to inner surface.

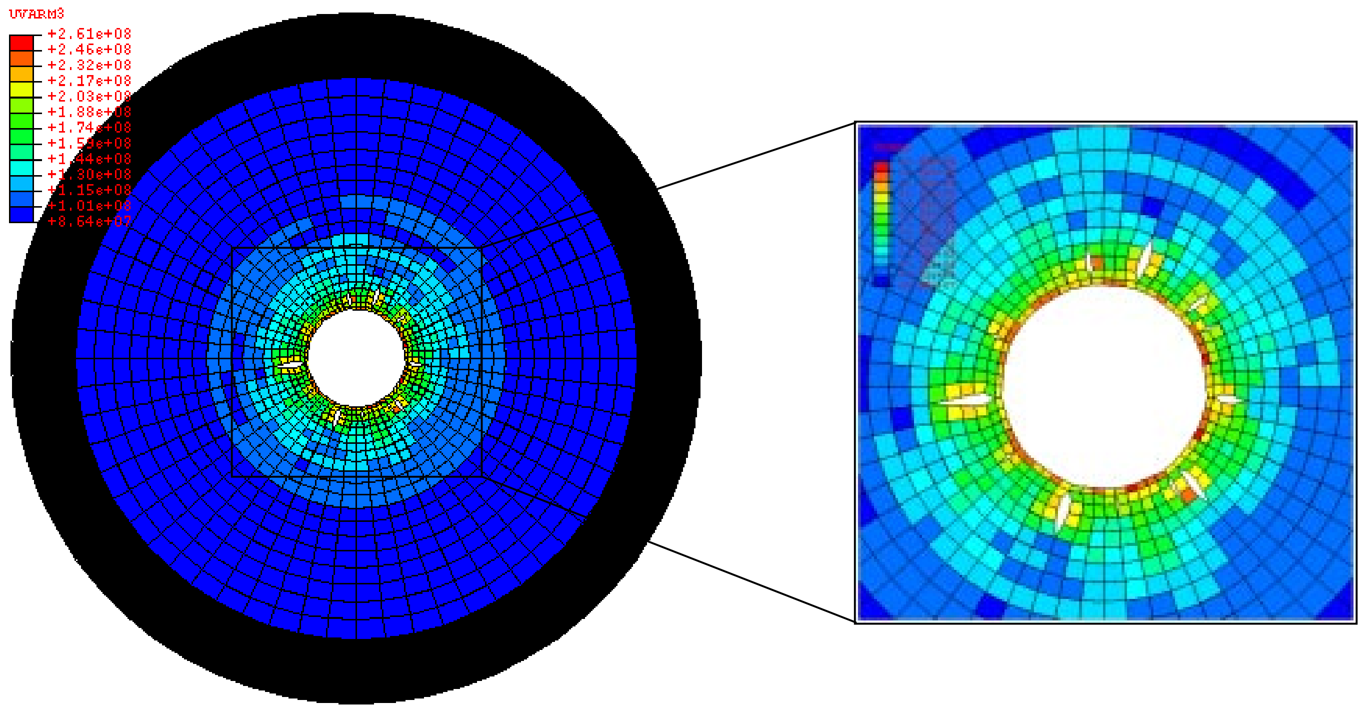
# Modeling the MCCO

- **Heat Up 120 K**
  - **Thermal Expansion Mismatch Causes Tensile Stress in Cu and Compressive Stress in HE**

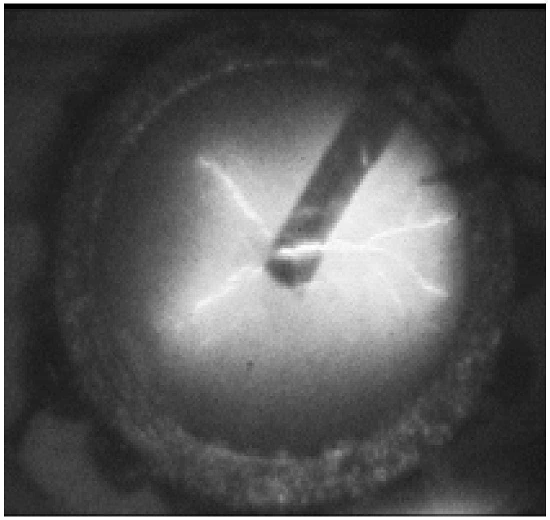


# Mechanically Coupled Cook Off

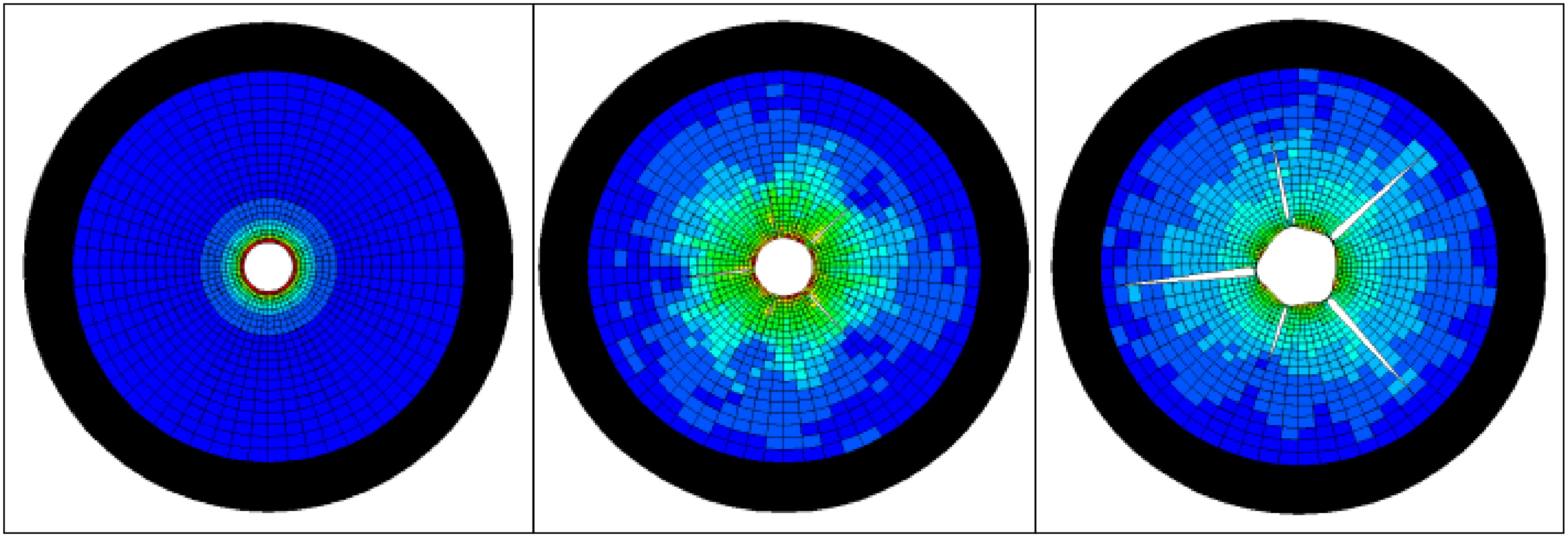
- Apply Pressure - 5MPa/μsec



# Modeling the MCCO



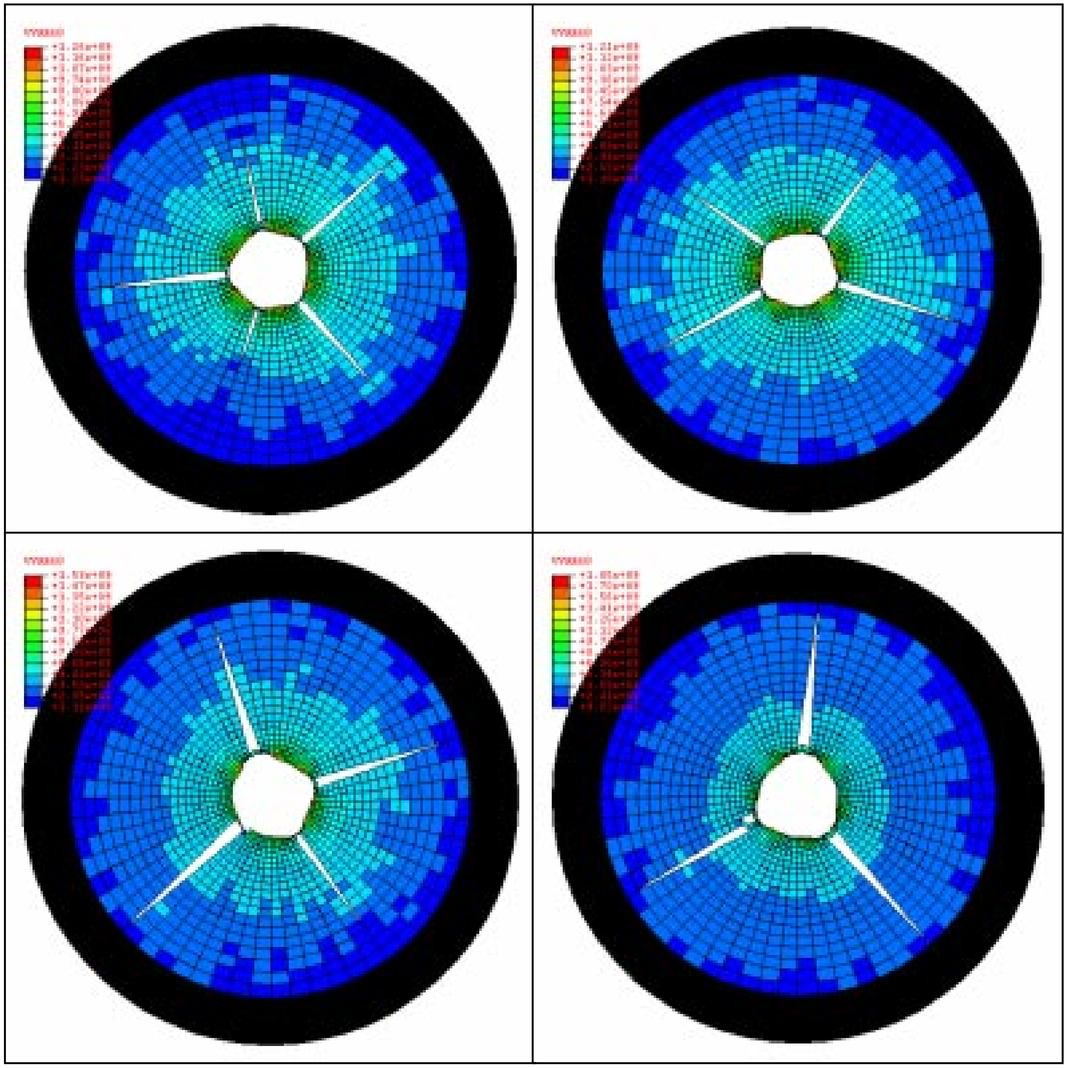
Effective Stress Contours:



t = 7.5 $\mu$sec t = 18.1 $\mu$sec t = 27.4 $\mu$sec

# Modeling the MCCO

- Different Random Distribution Results in Different Crack Pattern
- Always 3 to 5 Large Discrete Cracks



# ViscoSCRAM and MCCO

- ViscoSCRAM - An Engineering Material Model has been developed for ASCI STS Engineering Analysis Codes
  - Mechanical Validation “Complete”
  - Ignition Validation nearing Completion
- MCCO Modeling
  - Maturing Very Rapidly
  - DX Chemical Kinetics, and Steve Son’s Flame Front Propagation and Pressure Model are planned.

# “OUTWARD LOOK”

**Bennett, J.G., Haberman, K.S., Johnson, J.N., Asay, B.W. and Henson, B.F. (1998) “A Constitutive Model for the Non-Shock Ignition and Mechanical Response of High Explosives”, *J. Mech. Phys. Solids*, 46, 12, 2303-22.**

**Hackett, R. M., Bennett, J. G., “An Implicit Finite Element Model for Energetic Particulate Composite Materials,” submitted to *Int. J. Num. Meth. Eng*., LA-UR-99-3138, June, 1999.**

**Gerken, J. M., Smith, F. W., Bennett, J. G. (1999) “Numerical Simulation of the Mechanically Coupled Cook-Off Experiment” in preparation for submission to the ASME *J. Eng. Mat. and Tech.***